

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
25 July 2002 (25.07.2002)

PCT

(10) International Publication Number  
**WO 02/056795 A2**

(51) International Patent Classification<sup>7</sup>: **A61F 2/00**  
(21) International Application Number: **PCT/US02/01597**  
(22) International Filing Date: 18 January 2002 (18.01.2002)  
(25) Filing Language: English  
(26) Publication Language: English  
(30) Priority Data:  
09/765,725 18 January 2001 (18.01.2001) US  
(71) Applicant: **INTRATHERAPEUTICS, INC.** [US/US];  
651 Campus Drive, St. Paul, MN 55112 (US).

(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZM, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

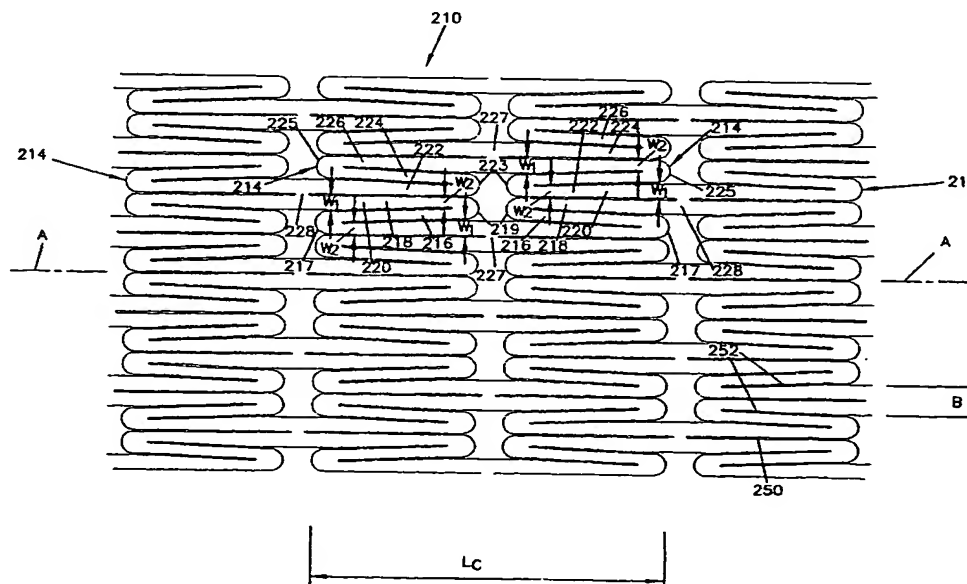
**Published:**

— without international search report and to be republished upon receipt of that report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(72) Inventor: **THOMPSON, Paul, J.**; 9125-40 1/2 Avenue North, New Hope, MN 55427 (US).  
(74) Agent: **BRUESS, Steven, C.**; Merchant & Gould P.C., P.O. Box 2903, Minneapolis, MN 55402-0903 (US).

(54) Title: **STENT**



(57) Abstract: The present disclosure relates to a stent including a stent body having a stent axis. The stent body includes structural members defining openings through the stent body. The structural members are provided with regions having different widths. The relative sizes of the widths are selected to control the length of the stent body as the stent body is radially expanded from an un-deployed orientation to a deployed orientation. In one embodiment, the regions having different widths are provided by tapering the widths of selected segments of the structural member.

WO 02/056795 A2

## STENT

This application is being filed as a PCT international patent application in the name of IntraTherapeutics, Inc., a U.S. national corporation, on 18 January 2002, designating all countries except the U.S.

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

This invention pertains to stents for use in intraluminal applications. More particularly, this invention pertains to a novel structure for such stents.

#### 2. Description of the Prior Art

Stents are widely used for numerous applications where the stent is placed in the lumen of a patient and expanded. Such stents may be used in coronary or other vasculature, as well as other body lumens.

Commonly, stents are cylindrical members. The stents expand from reduced diameters to enlarged diameters. Frequently, such stents are placed on a balloon catheter with the stent in the reduced-diameter state. So placed, the stent is advanced on the catheter to a placement site. At the site, the balloon is inflated to expand the stent to the enlarged diameter. The balloon is deflated and removed, leaving the enlarged diameter stent in place. So used, such stents are used to expand occluded sites within a patient's vasculature or other lumen.

Examples of prior art stents are numerous. For example, U.S. Patent No. 5,449,373 to Pinchasik et al. teaches a stent with at least two rigid segments joined by a flexible connector. U.S. Patent No. 5,695,516 to Fischell teaches a stent with a cell having a butterfly shape when the stent is in a reduced-diameter state. Upon expansion of the stent, the cell assumes a hexagonal shape.

In stent design, it is desirable for the stent to be flexible along its longitudinal axis to permit passage of the stent through arcuate segments of a patient's vasculature or other body lumen. Preferably, the stent will have at most minimal

longitudinal shrinkage when expanded and will resist compressive forces once expanded.

### **SUMMARY OF THE INVENTION**

5           The present disclosure relates to a stent including a stent body having a stent axis. The stent body includes structural members that define openings through the stent body. The structural members are provided with regions having different widths. The relative sizes of the widths are selected to control the length of the stent body as the stent body is radially expanded from an un-deployed orientation to a  
10       deployed orientation. In one embodiment, the regions having different widths are provided by tapering the widths of selected segments of the structural member. In a preferred embodiment, the relative sizes of the widths are selected to minimize or eliminate length changes as the stent body is expanded from the un-deployed orientation to the expanded orientation.

15

### **BRIEF DESCRIPTION OF THE DRAWINGS**

Fig. 1 is a perspective view of a first embodiment of a stent according to the present invention shown in a rest diameter state and showing a plurality of stent cells each having a major axis perpendicular to an axis of the stent;

20           Fig. 2 is a plan view of the stent of Fig. 1 as it would appear if it were longitudinally split and laid out flat;

Fig. 3 is the view of Fig. 2 following expansion of the stent to an enlarged diameter;

Fig. 4 is a view taken along line 4-4 in Fig. 2;

25           Fig. 5 is a view taken along line 5-5 in Fig. 2;

Fig. 6 is an enlarged view of a portion of Fig. 2 illustrating a cell structure with material of the stent surrounding adjacent cells shown in phantom lines;

Fig. 7 is the view of Fig. 2 showing an alternative embodiment of the present invention with a cell having five peaks per longitudinal segment;

30           Fig. 8 is the view of Fig. 2 showing an alternative embodiment of the present invention with a major axis of the cell being parallel to an axis of the stent; and

Fig. 9 is the view of Fig. 8 following expansion of the stent to an enlarged diameter;

Fig. 10 is a plan view of another stent as it would appear if it were longitudinally split and laid out flat;

5 Fig. 11 is an enlarged view of a portion of the stent of Fig. 10; and

Fig. 12 is a plan view of a portion of the stent of Fig. 10 in a deployed/expanded orientation, the stent has been longitudinally cut and laid flat.

### DESCRIPTION OF THE PREFERRED EMBODIMENT

10 Referring now to the several drawing figures in which identical elements are numbered identically, a description of the preferred embodiment of the present invention will now be provided. Where several embodiments are shown, common elements are similarly numbered and not separately described with the addition of apostrophes to distinguish the embodiments.

15 Fig. 1 illustrates a stent 10 having a rest length  $L_T$  and an un-deployed or reduced diameter  $D_T$ . For ease of illustration, the stent 10 is shown flat in Fig. 2 which illustrates a rest circumference  $C_T$  ( $C_T = \pi D_T$ ). In Fig. 2, locations A, B, C, D, E, F and G are shown severed from their normally integrally formed locations  $A_1$ ,  $B_1$ ,  $C_1$ ,  $D_1$ ,  $E_1$ ,  $F_1$  and  $G_1$ . This permits the stent 10 to be shown as if it were  
20 severed at normally integrally formed locations A-  $A_1$ , B-  $B_1$ , C-  $C_1$ , D-  $D_1$ , E-  $E_1$ , F-  $F_1$  and G-  $G_1$  and laid flat. Fig. 6 is an enlarged portion of the view of Fig. 2 to better illustrate a novel cell structure as will be described.

The stent 10 is a reticulated, hollow tube. The stent 10 may be expanded from the rest diameter  $D_T$  (and corresponding rest circumference  $C_T$ ) to an expanded  
25 or enlarged diameter. Fig. 3 is a view similar to Fig. 2 (i.e., illustrating the expanded stent 10 as it would appear if longitudinally split and laid flat). Since Fig. 3 is a two-dimensional representation, the enlarged diameter is not shown. However, the enlarged circumference  $C_e$  is shown as well as a length  $L_e$  following expansion. The expanded diameter is equal to  $C_e/\pi$ .

30 As will be discussed length  $L_e$  is preferably not more than minimally smaller (e.g., less than 10% smaller) than length  $L_T$ . Ideally,  $L_e$  equals  $L_T$ .

The material of the stent 10 defines a plurality of cells 12. The cells 12 are bounded areas which are open (i.e., extend through the wall thickness of the stent 10). The stent 10 may be formed through any suitable means including laser or chemical milling. In such processes, a hollow cylindrical tube is milled to remove  
 5 material and form the open cells 12.

The cells 12 have a longitudinal or major axis  $X_M-X_M$  and a transverse or minor axis  $X_m-X_m$ . In the embodiments of Figs. 1 - 3, the major axis  $X_M-X_M$  is perpendicular to the longitudinal cylindrical axis  $X-X$  of the stent 10. In the  
 10 embodiments of Figs. 8 and 9, the major axis  $X_M'-X_M'$  is parallel to the longitudinal cylindrical axis  $X'-X'$  of the stent 10'. The cell 12 is symmetrical about axes  $X_M-X_M$  and  $X_m-X_m$ .

The cell 12 is defined by portions of the tube material including first and second longitudinal segments 14. The segments 14 each have a longitudinal axis  $X_a-X_a$  as shown in Fig. 6. The segments' longitudinal axes  $X_a-X_a$  are parallel to  
 15 and positioned on opposite sides of the cell major axis  $X_M-X_M$ .

Each of longitudinal segments 14 has an undulating pattern to define a plurality of peaks 17, 21, 25 and valleys 19, 23. The peaks 17, 21, 25 are spaced outwardly from the longitudinal axes  $X_a-X_a$  and the valleys 19, 23 are spaced inwardly from the longitudinal axes  $X_a-X_a$ . As used in this context, "inward" and  
 20 "outward" mean toward and away from, respectively, the cell's major axis  $X_M-X_M$ .

Each of the peaks 17, 21, 25 and valleys 19, 23 is a generally semi-circular arcuate segment. The peaks 17, 21, 25 and valleys 19, 23 are joined by parallel and spaced-apart straight segments 16, 18, 20, 22, 24 and 26 which extend perpendicular to the major axis  $X_M-X_M$ . Linearly aligned straight end portions 16, 26 of  
 25 opposing segments 14 are joined at first and second longitudinal connection locations 27 spaced apart on the major axis  $X_M-X_M$ . First and second transverse connection locations 28 are spaced apart on the minor axis  $X_m-X_m$ . The first and second transverse connection locations 28 are positioned at the apices of the center peaks 21 of the longitudinal segments 14.

30 Except as will be described, the segments 14 have uniform cross-sectional dimensions throughout their length as illustrated in Fig. 4. By way of non-limiting example, the width  $W$  and thickness  $T$  of the straight line segments 16, 18, 20, 22,

24 and 26 are about .0065 inch (about .16 mm) and about .0057 inch (about .14 mm), respectively.

For reasons that will be described, the width  $W'$  (Fig. 5) at the apices of the peaks 17, 21, 25 and valleys 19, 23 is narrower than width  $W$  (in the example given, narrow width  $W'$  is about .0055 inch or about .13 mm). The width of the peaks 17, 21, 25 and valleys 19, 23 gradually increases from width  $W'$  at the apices to width  $W$  at the straight segments 16, 18, 20, 22, 24 and 26. At the longitudinal and transverse connection locations 27, 28, the width  $W_C$  (shown in Fig. 2) is preferably equal to or less than the common width  $W$ .

The combined lengths of segments 16 - 20 to the apex of peak 21 represent a path length 50 from longitudinal connection location 27 to transverse connection location 28. Similarly the combined lengths of the other arcuate and straight segments 22 — 26 to the apex of peak 21 represent identical length path lengths 51 of identical geometry from longitudinal connection locations 27 to transverse connection locations 28. Each of the path lengths 50, 51 is longer than a straight-line distance between the transverse and longitudinal connection locations 27, 28. As will be described, the straight-line distance between the transverse and longitudinal connection locations 27, 28 increases as the diameter of the stent 10 is expanded. The path lengths 50, 51 are sized to be not less than the expanded straight-line distance.

The stent 10 includes a plurality of identical cells 12. Opposite edges of the segments 14 define obliquely adjacent cells (such as cells  $12_1$ ,  $12_2$  in Fig. 2). Cells 12 having major axes  $X_M$ - $X_M$  collinear with the major axis  $X_M$ - $X_M$  of cell 12 are interconnected at the longitudinal connection locations 27. Cells having minor axes collinear with the minor axis  $X_m$ - $X_m$  of cell 12 are interconnected at the transverse connection locations 28.

As mentioned, the stent 10 in the reduced diameter of Fig. 1 is advanced to a site in a lumen. The stent 10 is then expanded at the site. The stent 10 may be expanded through any conventional means. For example, the stent 10 in the reduced diameter may be placed on the balloon tip of a catheter. At the site, the balloon is expanded to generate radial forces on the interior of the stent 10. The radial forces urge the stent 10 to radially expand without appreciable longitudinal expansion or

contraction. Plastic deformation of the material of the stent 10 (e.g., stainless steel) results in the stent 10 retaining the expanded shape following subsequent deflation of the balloon. Alternatively, the stent 10 may be formed of a super-elastic or shape memory material (such as nitinol --- a well-known stent material which is an alloy of  
 5 nickel and titanium).

As the stent 10 expands, the path lengths 50, 51 straighten to accommodate the expansion. Fig. 3 illustrates the straightening of the path lengths 50, 51. In Fig. 3, the stent 10 has been only partially expanded to an expanded diameter less than a maximum expanded diameter. At a maximum expanded size, the path lengths 50,  
 10 51 are fully straight. Further expansion of the stent 10 beyond the maximum expanded size would result in narrowing of the minor axis  $X_m-X_m$  (i.e., a narrowing of a separation between the transverse connection locations and a resulting narrowing of the length  $L_T$  of the stent) or would require stretching and thinning of the stent material.

As shown in Fig. 3, during expansion of the stent 10, the straight segments 16, 18, 20, 22, 24 and 26 are substantially unchanged. The straightening of the path lengths 50, 51 results in bending of the arcuate peaks 17, 21, 25 and valleys 19, 23. Since the width  $W'$  of the peaks 17, 21, 25 and valleys 19, 23 is less than the width  
 15  $W$  of the straight segments 16, 18, 20, 22, 24 and 26, the arcuate peaks 17, 21, 25 and valleys 19, 23 are less stiff than the straight segments 16, 18, 20, 22, 24 and 26  
 20 and, therefore, more likely to deform during expansion.

As the stent 10 expands, the cells 12 assume a diamond shape shown in Fig. 3. Since the expansion forces are radial, the length of the major axis  $X_M-X_M$  (i.e., the distance between the longitudinal connection locations 27) increases. The length  
 25 of the minor axis  $X_m-X_m$  (and hence the length of the stent 10) remains unchanged.

The stent 10 is highly flexible. To advance to a site, the axis X-X of the stent 10 must bend to navigate through a curved lumen. Further, for placement at a curved site in a lumen, the stent 10 must be sufficiently flexible to retain a curved shape following expansion and to bend as the lumen bends over time. The stent 10,  
 30 as described above, achieves these objections.

When bending on its axis X-X, the stent 10 tends to axially compress on the inside of the bend and axially expand on the outside of the bend. The present design

permits such axial expansion and contraction. The novel cell geometry 12 results in an accordion-like structure which is highly flexible before and after radial expansion. Further, the diamond shape of the cells 12 after radial expansion resists constricting forces otherwise tending to collapse the stent 10.

5        Numerous modifications are possible. For example the stent 10 may be lined with either an inner or outer sleeve (such as polyester fabric or ePTFE) for tissue growth. Also, the stent may be coated with radiopaque coatings such as platinum, gold, tungsten or tantalum. In addition to materials previously discussed, the stent may be formed of any one of a wide variety of previous known materials including, 10 without limitation, MP35N, tantalum, platinum, gold, Elgiloy and Phynox.

While three cells 12 are shown in Fig. 2 longitudinally connected surrounding the circumference  $C_T$  of the stent, a different number could be so connected to vary the properties of the stent 10 as a designer may elect. Likewise, while each column of cells 12 in Fig. 2 is shown as having three longitudinally 15 connected cells 12, the number of longitudinally connected cells 12 could vary to adjust the properties of the stent. Also, while each longitudinal segment 14 is shown as having three peaks 17, 21, 25 per longitudinal segment 14, the number of peaks could vary. Fig. 7 illustrates a stent 10" with a cell 12" having five peaks 17", 21", 25" and 125" per longitudinal segment 14". Preferably, the longitudinal 20 segment will have an odd number of peaks so that the transverse connection points are at an apex of a center peak.

Figs. 8 and 9 illustrate an alternative embodiment where the major axis  $X_M'$ - $X_M'$  of the cells 12' are parallel with the cylindrical axis  $X'-X'$  of the stent 10'. In Fig. 9, the expanded stent 10' is shown at a near fully expanded state where the path 25 lengths 50', 51' are substantially linear.

When forming the stent from shape memory metal such as nitinol, the stent can be laser cut from a nitinol tube. Thereafter, the stent can be subjected to a shape-setting process in which the cut tube is expanded on a mandrel and then heated. Multiple expansion and heating cycles can be used to shape-set the stent to 30 the final expanded diameter. Preferably, the final expanded diameter is equal to the desired deployed diameter of the stent. During expansion, the stent is preferably axially restrained such that the length of the stent does not change during expansion.



The finished stent preferably has an austenite finish temperature less than body temperature. Thus, at body temperature, the stent will self-expand to the desired deployed diameter due to the shape memory characteristic of the metal forming the stent.

5 In use, the finished stent can be mounted on a delivery catheter. As is conventionally known in the art, the stent can be held in a compressed orientation on the delivery catheter by a retractable sheath. As is also known in the art, the delivery catheter can be used to advance the stent to a deployment location (e.g., a constricted region of a vessel). At the deployment cite, the sheath is retracted thereby releasing  
10 the stent. Once released, the stent self-expands to the deployed diameter.

It has been noted that the lengths of prior art stents when mounted on a delivery catheter can be different from the deployed lengths of such stents. For example, it has been determined that the deployed lengths of the prior art stents are often shorter than the compressed orientation lengths (i.e., the lengths of the stents  
15 when mounted on a delivery catheter). Shortening can be problematic because shortening makes it more difficult for a physician to accurately place a stent at a desired position in a vessel.

An important aspect of the present invention relates to a stent design that reduces or eliminates shortening of a stent. For example, one embodiment of the  
20 present invention relates to a stent having the same length or substantially the same length at each of the following stages: 1) when the stent is initially cut from a tube of shape-memory alloy; 2) when the stent is shape-set to the desired expanded diameter; 3) when the stent is compressed on the delivery catheter; and 4) when the stent is deployed at a deployment location.

25 With respect to shape memory stents, it has been found that varying the width of the segments 16, 18, 20, 22, 24 and 26 controls whether the stent shortens, lengthens, or remains the same length during expansion from the compressed orientation (i.e., the reduced diameter orientation) to the deployed orientation. For example, the segments 26 and 16 are preferably constructed with enlarged widths  
30 adjacent the connection locations 27, and reduced widths adjacent their corresponding peaks 25 and 17. Similarly, the segments 22 and 20 are preferably constructed with enlarged widths adjacent the connection locations 28, and reduced

widths adjacent their corresponding valleys 23 and 19. The relative sizes between the enlarged widths and the reduced widths controls whether the stent shortens, lengthens, or remains the same during expansion.

5 Figs. 10-12 show a stent 210 having a cell structure adapted to limit any length changes that may occur as the stent is expanded from the compressed orientation to the deployed orientation. Preferably the length change between the compressed orientation and the deployed orientation is less than 5 percent. More preferably, the length change between the compressed orientation and the deployed orientation is less than 2 percent. Most preferably, the stent 210 experiences  
10 substantially no length change as it is released from a delivery catheter and expanded from the compressed orientation to the deployed orientation.

Fig. 10 shows the stent 210 cut longitudinally along its length and laid flat. The stent 210 has a length L and a circumference C. Fig. 10 is representative of the stent 210 after the stent 210 has been laser cut from a shape-memory tube, but before  
15 the stent 210 has been shape-set to the expanded diameter. Fig. 12 shows a portion of the stent 210 after the stent has been shape-set to the desired expanded diameter. In both Figs. 10 and 12, the stent 210 is elongated along axis A-A and includes a stent body (i.e., a three-dimensional structure) having cell defining portions that define  
• plurality of cells 212. After the stent 210 has been shape-set to the expanded  
20 diameter as shown in Fig. 12, the cells 212 are preferably more open than the cells 212 depicted in Fig. 10. However, while the circumference C increases, the length L preferably remains substantially the same at both diameters.

Referring to Fig. 11, the cell defining portions of the stent body include circumferential connection locations 227 and longitudinal connection locations 228.  
25 "Circumferential connection locations" are locations where circumferentially adjacent cell defining structures, as defined relative to axis A-A, are connected together. "Longitudinal connection locations" are locations where longitudinally adjacent cell defining portions, as defined relative to the axis A-A, are connected together.

30 Referring still to Fig. 11, each cell defining portion includes two axially spaced-apart members 214 (i.e., members that are spaced-apart from one another along the axis A-A) that extend circumferentially about the axis A-A in an

undulating pattern. The members 214 extend in the undulating pattern between the circumferential connection locations 227. Adjacent the circumferential connection locations 227, the ends of the undulating members 214 are connected to one another. At the longitudinal connection locations 228, the undulating members 214 merge  
5 with the undulating members 214 of longitudinally adjacent cell defining portions.

Still referring to Fig. 11, each undulating member 214 is shown including: 1) a segment 226 that extends from connection location 227 to peak 225; 2) a segment 224 that extends from peak 225 to valley 223; 3) a segment 222 that extends from valley 223 to connection location 228; 4) a segment 220 that extends from  
10 connection location 228 to valley 219; 5) a segment 218 that extends from valley 219 to peak 217; and 6) a segment 216 that extends from peak 217 to connection location 227. The segments 216-226 preferably extend generally longitudinally along the stent 210. The term "generally longitudinally" will be understood to mean that the segments 216-226 are closer to a parallel relationship relative to the axis A-A  
15 A of the stent 210 than to a transverse relationship relative to the axis A-A of the stent 210.

To prevent length changes during deployment of the stent, the segments 226 and 216 preferably include enlarged widths  $W_1$  adjacent the connection locations 227, and reduced widths  $W_2$  adjacent their corresponding peaks 225 and 217.  
20 Similarly, the segments 222 and 220 are preferably constructed with enlarged widths  $W_1$  adjacent the connection locations 228, and reduced widths  $W_2$  adjacent their corresponding valleys 223 and 219. Preferably, widths of the segments 226, 222, 220 and 216 taper (i.e., narrow) continuously along their lengths. As is clear from Fig. 11, the widths of the segments are measured in a circumferential direction  
25 relative to the axis A-A.

Referring once again to Fig. 11, pairs of tapered segments 226 and 216 are provided at each circumferential connection location 227, and pairs of tapered segments 222 and 220 are provided at each longitudinal connection location 228. Each pair of tapered segments is defined by an inner cut 250 that is parallel to the  
30 axis A-A of the stent 210, and two outer cuts 252 that are angled relative to the axis A-A of the stent 210. Preferably, the outer cuts 252 diverge from one another as the cuts 252 extend toward their corresponding connection location 227 or 228. The

angled orientation of the cuts 252 causes the segments 224 and 218 which interconnect the pairs of tapered segments 226, 216, 222 and 220 to have a non-tapered configuration. Additionally, the angled orientation of the cuts 252 causes the segments 224 and 218 to be angled (i.e., skewed) relative to the axis A-A of the stent 210.

The narrowing from width  $W_1$  to  $W_2$  results in a taper along the lengths of the segments 226, 222, 220 and 216. Preferably, the taper has an angle B in the range of .5-5 degrees relative to the axis A-A of the stent 210. More preferably, the taper angle B is in the range of 1-3 percent. It has been found that the relative sizes of  $W_1$  and  $W_2$  have an effect on the deployed length of the stent 210 (i.e., the length of the stent after deployment in a vessel) as compared to the compressed length of the stent 210 (i.e., the length of the stent when mounted on a delivery catheter). As a result, in the design of the stent, the widths  $W_1$  and  $W_2$  can be selected to effect a desired change in length including no change in length if so desired. For example, a stent having a 5 millimeter cell length  $L_c$  (labeled on Fig. 11), a first width  $W_1$  of .0065 inch and a second width  $W_2$  of .0059 inch, has been found to lengthen about 10% during expansion from the compressed orientation to the deployed orientation. Alternatively, a stent having a 5 millimeter cell length  $L_c$  (labeled on Fig. 11), a first width  $W_1$  of .009 and a second width  $W_2$  of .0047, has been found to shorten about 10% during expansion from the compressed orientation to the deployed orientation. Further, a stent with a 5 millimeter cell length  $L_c$  (labeled on Fig. 11), a first width  $W_1$  of .008 inches, a second width  $W_2$  of .0052 inches and an angle B of two degrees has been found to experience no lengthening and no shortening when expanded from the compressed orientation and the deployed orientation.

While a preferred use for the inventive features disclosed in Figs. 10-12 is in a self-expanding stent, the features also have benefits when used with non-self-expanding stents (e.g., balloon expandable stents made of a material such as stainless steel). Also, while Figs. 10-12 illustrate a preferred geometry for practicing the present invention, the technique for controlling length variations by varying the widths of selected portions of a stent is also applicable to stents having other geometries, shapes, or strut patterns. Further, the various aspects of the present

invention can also be used to cause a desired shortening or lengthening of a stent during deployment.

From the foregoing, the present invention has been shown in a preferred embodiment. Modifications and equivalents are intended to be included within the  
5 scope of the appended claims.

What is claimed is:

1. A stent comprising:  
a stent body having a stent axis;  
5 the stent body including a structural member extending in an undulating pattern about a circumference of the stent body;  
the structural member including a plurality of segments that extend generally longitudinally along the stent axis; and  
at least some of the segments having widths that taper as the at least some  
10 segments extend longitudinally along the stent axis.
2. The stent of claim 1, wherein a taper angle of the widths is selected to minimize a length change of the stent body as the stent body is radially expanded from an un-deployed orientation to a deployed orientation.
- 15 3. The stent of claim 1, wherein the at least some segments include pairs of tapered segments, the pairs of tapered segments being interconnected by non-tapered segments.
- 20 4. The stent of claim 3, wherein the non-tapered segments are skewed relative to the stent axis.
5. The stent of claim 1, wherein the segments are substantially straight.
6. The stent of claim 1, wherein the stent body is made of a shape-memory  
25 metal.
7. A stent comprising:  
a stent body having a stent axis;  
the stent body including a plurality of cell structures defining a plurality of  
30 cells;  
the cell structures including structural members that extend in an undulating pattern about a circumference of the stent body;

the structural members including segments that extend generally longitudinally along the stent axis;

the structural members including peaks and valleys;

the cell structures being interconnected at connection locations;

5       at least some of the segments extending from the connection locations to the peaks and valleys; and

the at least some segments having enlarged first widths adjacent the connection locations as compared to smaller second widths located adjacent the peaks and valleys.

10

8.       The stent of claim 7, wherein the at least some of the segments are provided with a narrowing width taper that extends between the first and second widths.

9.       The stent of claim 7, wherein the relative sizes of the first and second widths  
15       are selected to minimize a length change of the stent body as the stent body is radially expanded from an un-deployed orientation to a deployed orientation.

10.       The stent of claim 7, wherein the at least some segments include pairs of tapered segments positioned at the connection locations, the pairs of tapered  
20       segments being interconnected by non-tapered segments.

11.       The stent of claim 10, wherein the non-tapered segments are skewed relative to the stent axis.

25       12.       The stent of claim 7, wherein the segments are straight.

13.       The stent of claim 7, wherein the connection locations include longitudinal connection locations and circumferential connection locations.

30       14.       The stent of claim 13, wherein the cells are symmetrical about first axes extending through the circumferential connection locations, and the cells are also

symmetrical about second axes extending through the longitudinal connection locations.

15. A stent comprising:
- 5 a stent body having a stent axis;  
the stent body including a structural member extending in an undulating pattern about a circumference of the stent body;  
the structural member including peaks and valleys, and also including segments that interconnect the peaks and valleys; and
- 10 at least some of the segments having widths that taper along lengths of the at least some segments.
16. The stent of claim 15, wherein the segments are substantially straight.
- 15 17. The stent of claim 15, wherein the structural members form cell structures that are interconnected at connection locations, and wherein the at least some segments have larger widths adjacent the connection locations than adjacent the peaks and valleys.
- 20 18. The stent of claim 15, wherein a taper angle of the widths is selected to control a length change of the stent body as the stent body is radially expanded from an un-deployed orientation to a deployed orientation.
19. The stent of claim 18, wherein the taper angle is selected to minimize a
- 25 length change of the stent body as the stent body is expanded from the un-deployed orientation to the deployed orientation.



20. A stent comprising:  
a stent body having a stent axis, the stent body being radially expandable from a non-deployed orientation having a first length to a deployed orientation having a second length;
- 5 the stent body including a structural member extending in an undulating pattern about a circumference of the stent body; and  
the first length being substantially equal to the second length.
21. A method for making a stent, the method comprising:  
10 constructing a stent body having a stent axis, the stent body including structural members defining openings through the stent body; and  
during construction of the stent body, providing at least some of the structural members with regions having first and second different widths, the relative sizes of the first and second widths being selected to control a length of the stent  
15 body as the stent body is radially expanded from an un-deployed orientation to a deployed orientation.
22. The method of claim 21, wherein the relative sizes of the widths are selected to minimize a length variation when the stent body is radially expanded from the un-  
20 deployed orientation to the deployed orientation.
23. The method of claim 21, further comprising providing the structural members with a gradual taper in width between the first and second widths.
- 25 24. The method of claim 23, wherein the segments are substantially straight.
25. The method of claim 21, further comprising shape-setting the stent body to an expanded diameter corresponding to the deployed orientation after the stent body has been constructed.
- 30 26. The method of claim 21, wherein the structural members extend in undulating patterns.

27. A stent comprising:

a stent body that is radially expandable from an un-deployed orientation to a deployed orientation;

5 the stent body including structural members defining openings through the stent body;

the structural members including segments having first regions with enlarged widths and second regions with more narrow widths; and

10 the relative sizes of the enlarged widths and the more narrow widths are selected to control a length of the stent body as the stent body is expanded from the un-deployed orientation to the deployed orientation.

28. The stent of claim 27, wherein the relative sizes of widths are selected to minimize a change in the length of the stent body as the stent body is expanded from  
15 the un-deployed orientation to the deployed orientation.

29. The stent of claim 27, wherein widths of the segments gradually taper between the enlarged widths and the more narrow widths.

20 30. The stent of claim 29, wherein the segments are substantially straight between the first regions and the second regions.

31. The stent of claim 30, wherein between the first and second regions, the segments extend in a generally longitudinal direction relative to an axis of the stent.

25

FIG. 1

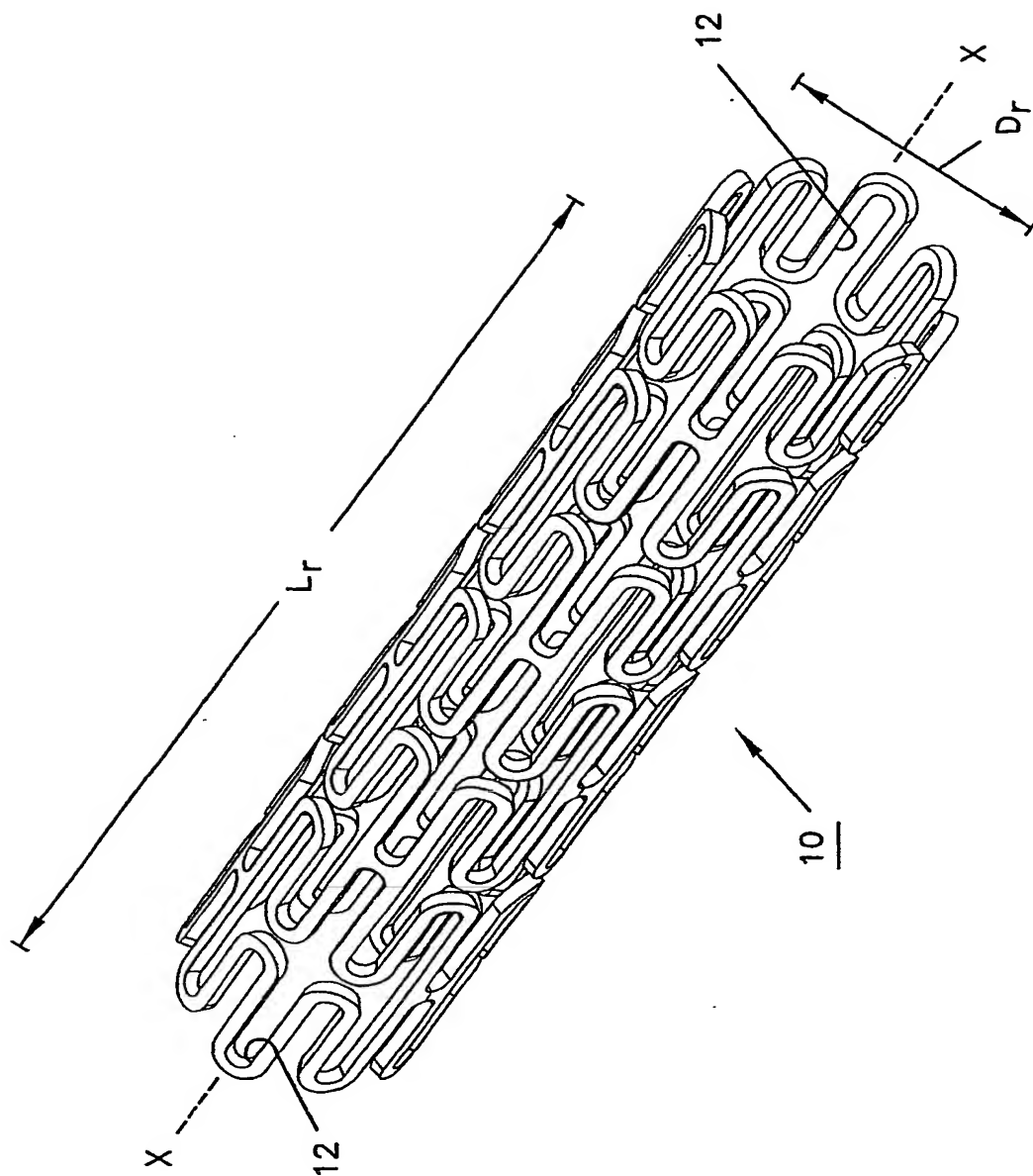
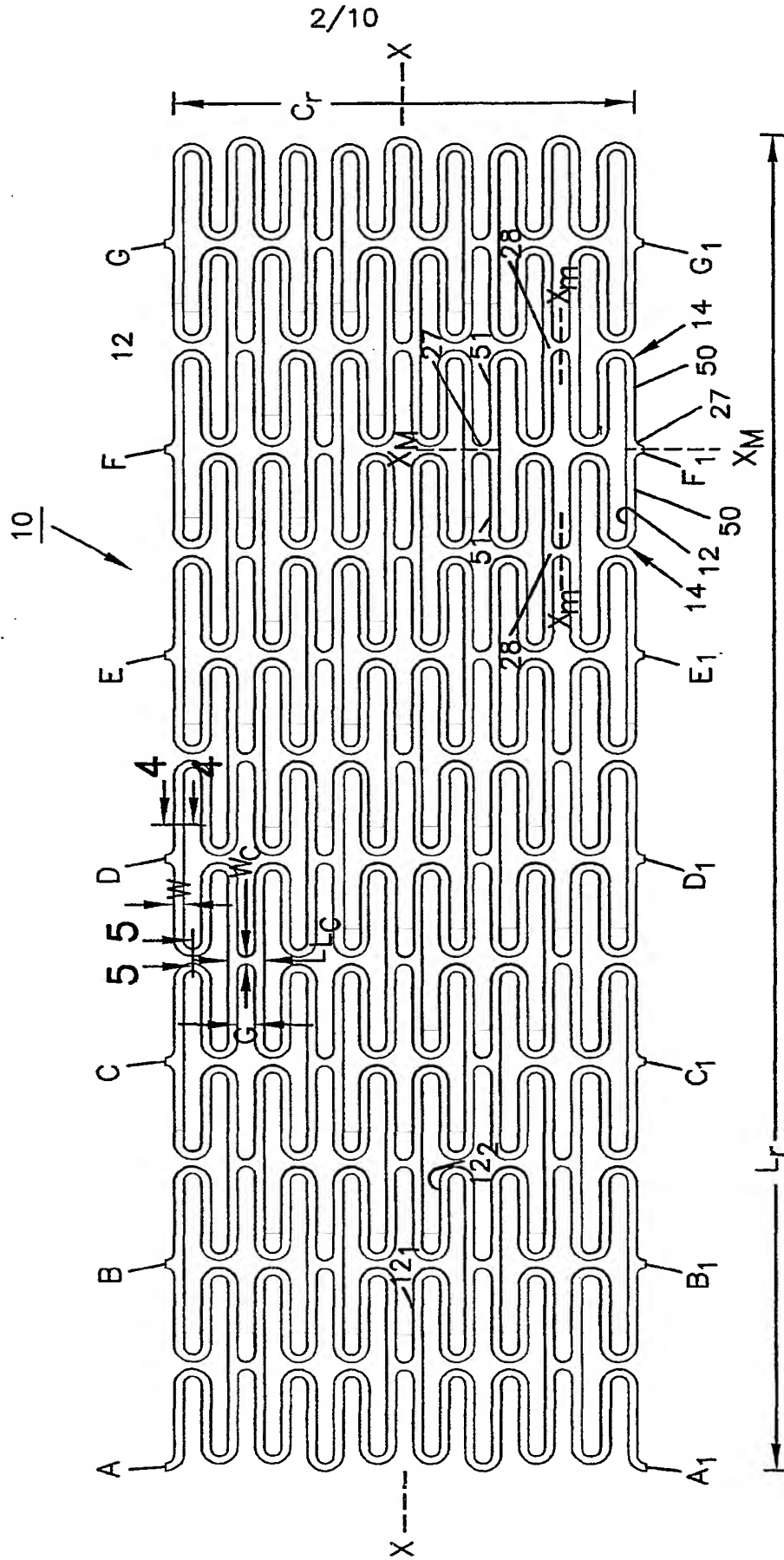
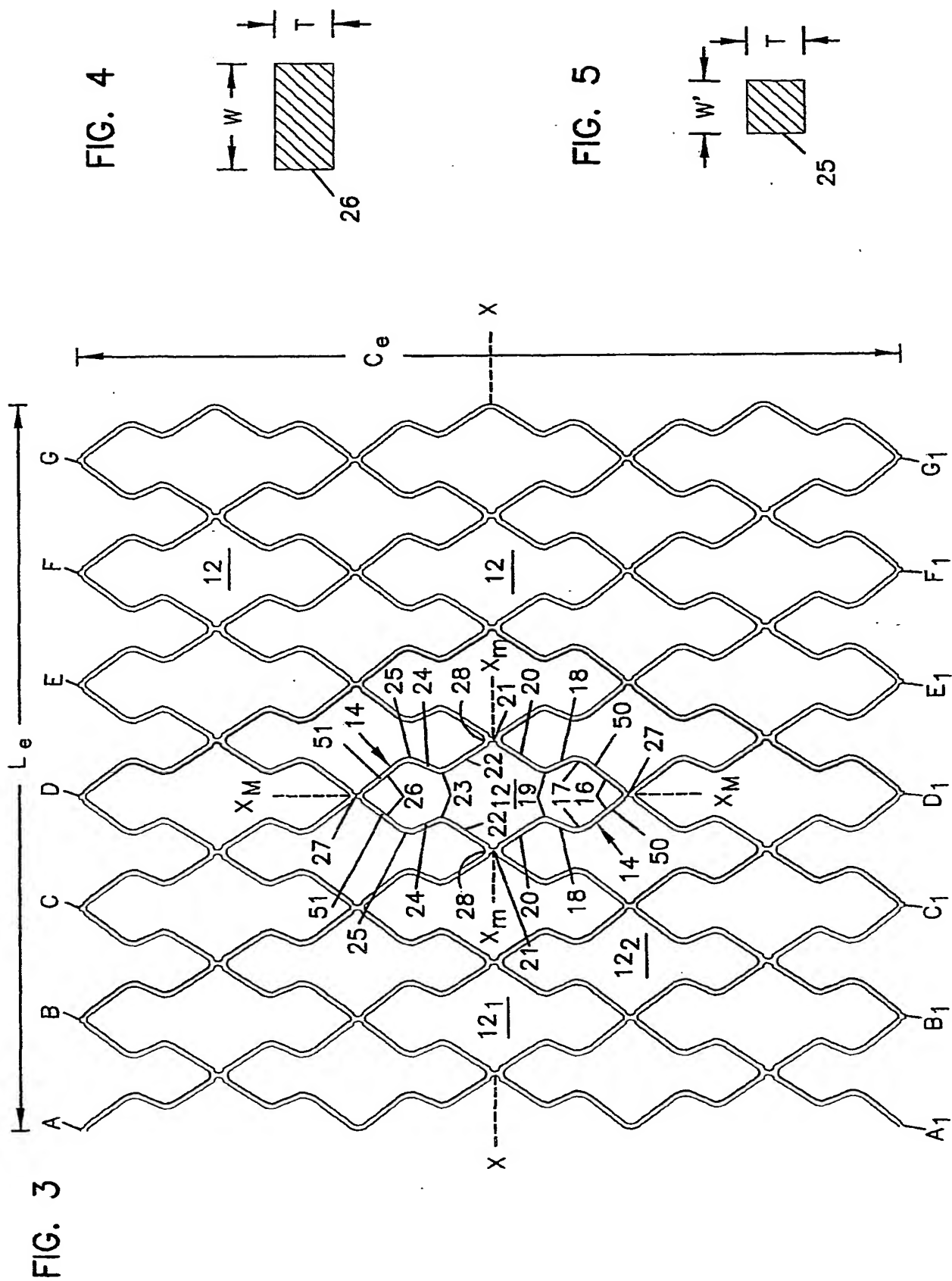


FIG. 2





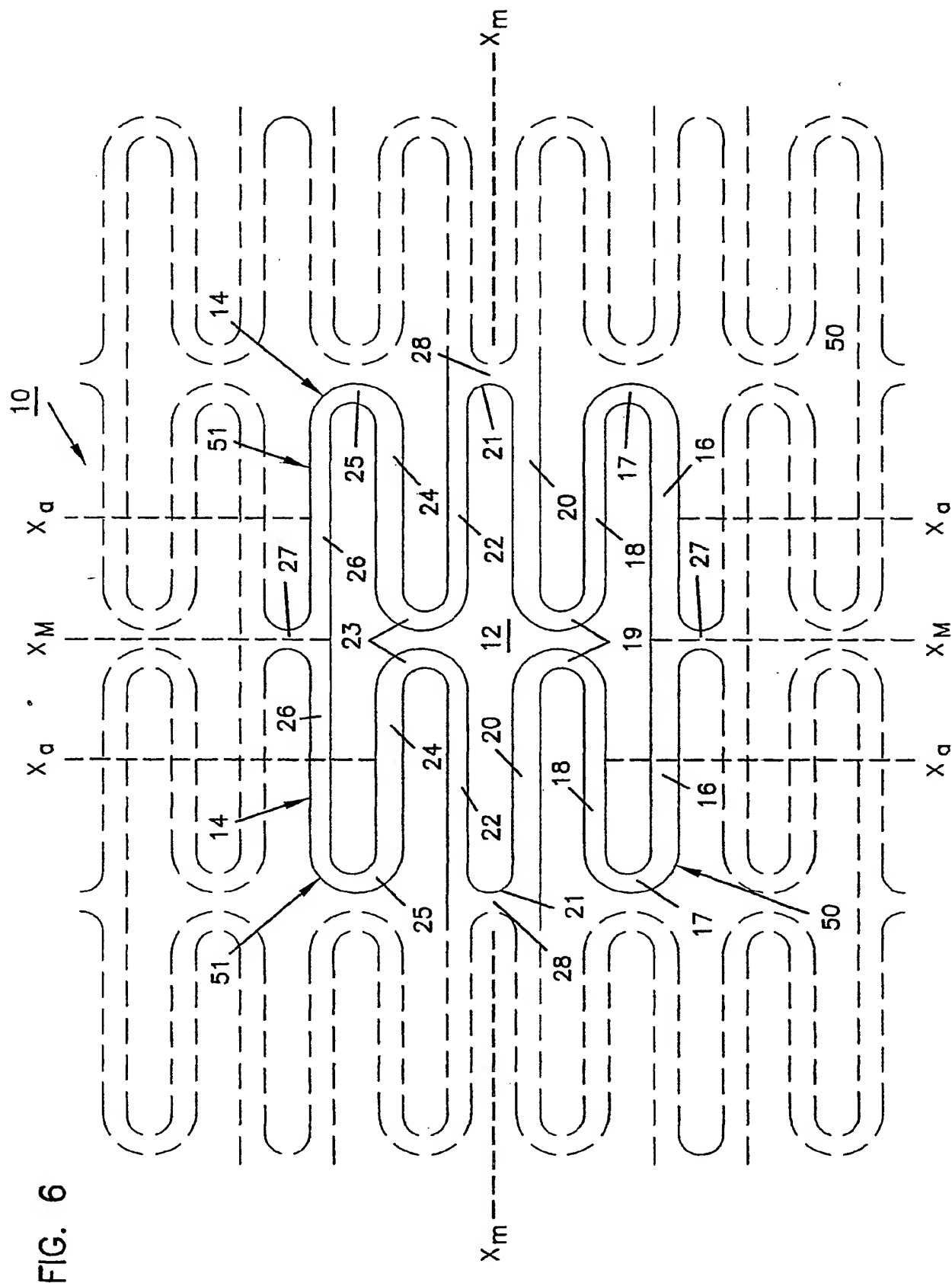
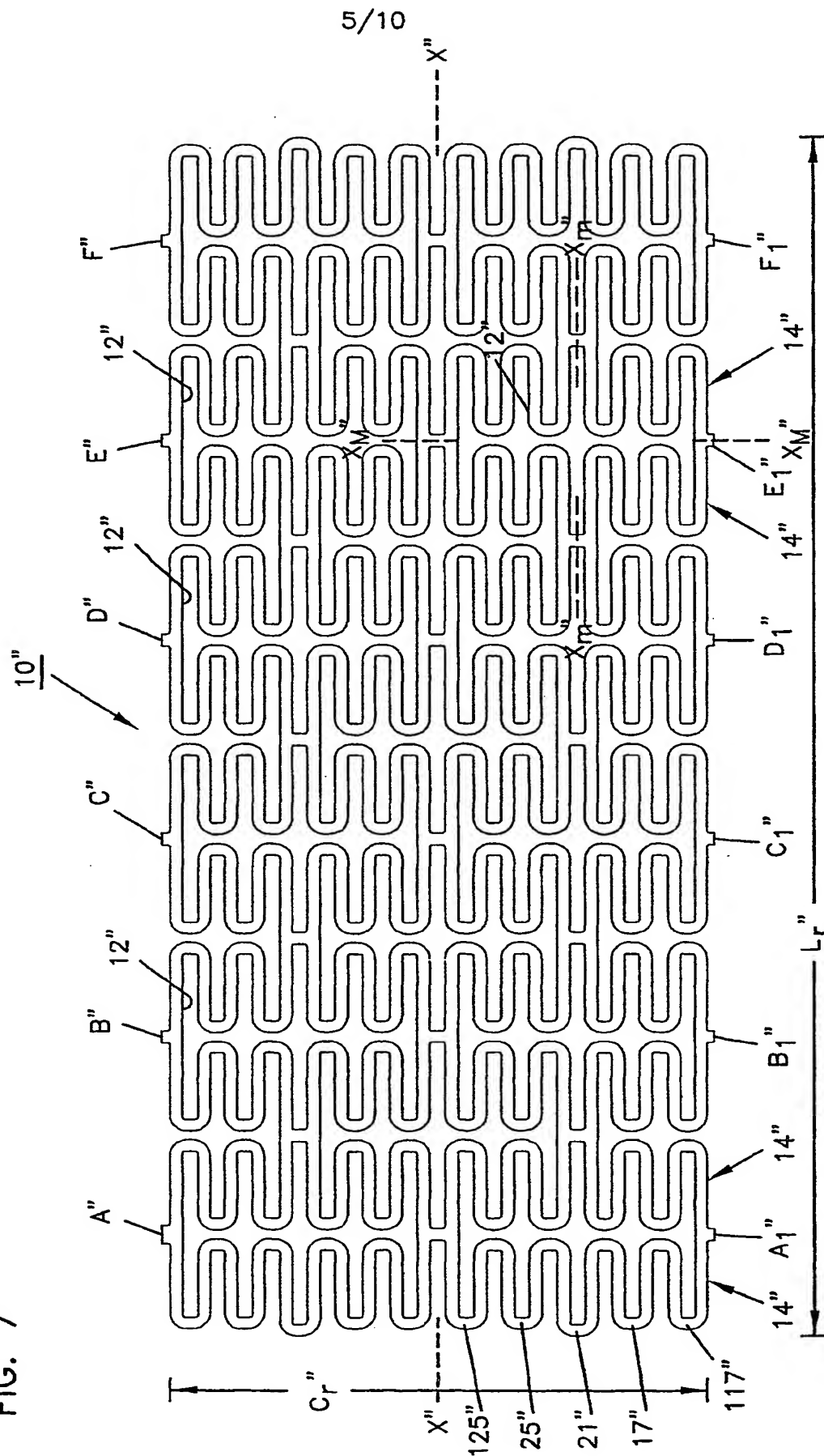
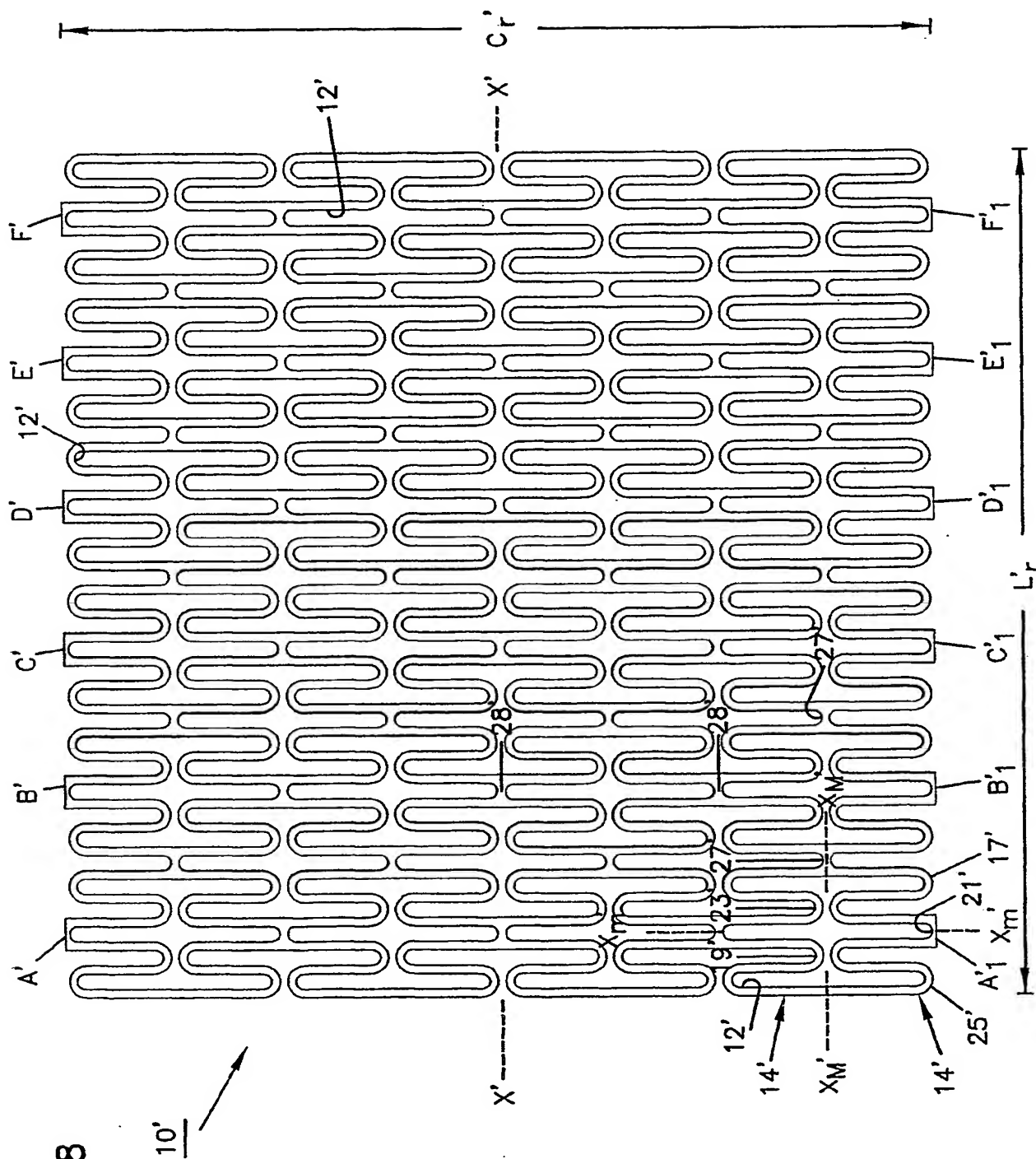


FIG. 7







7/10

FIG. 9

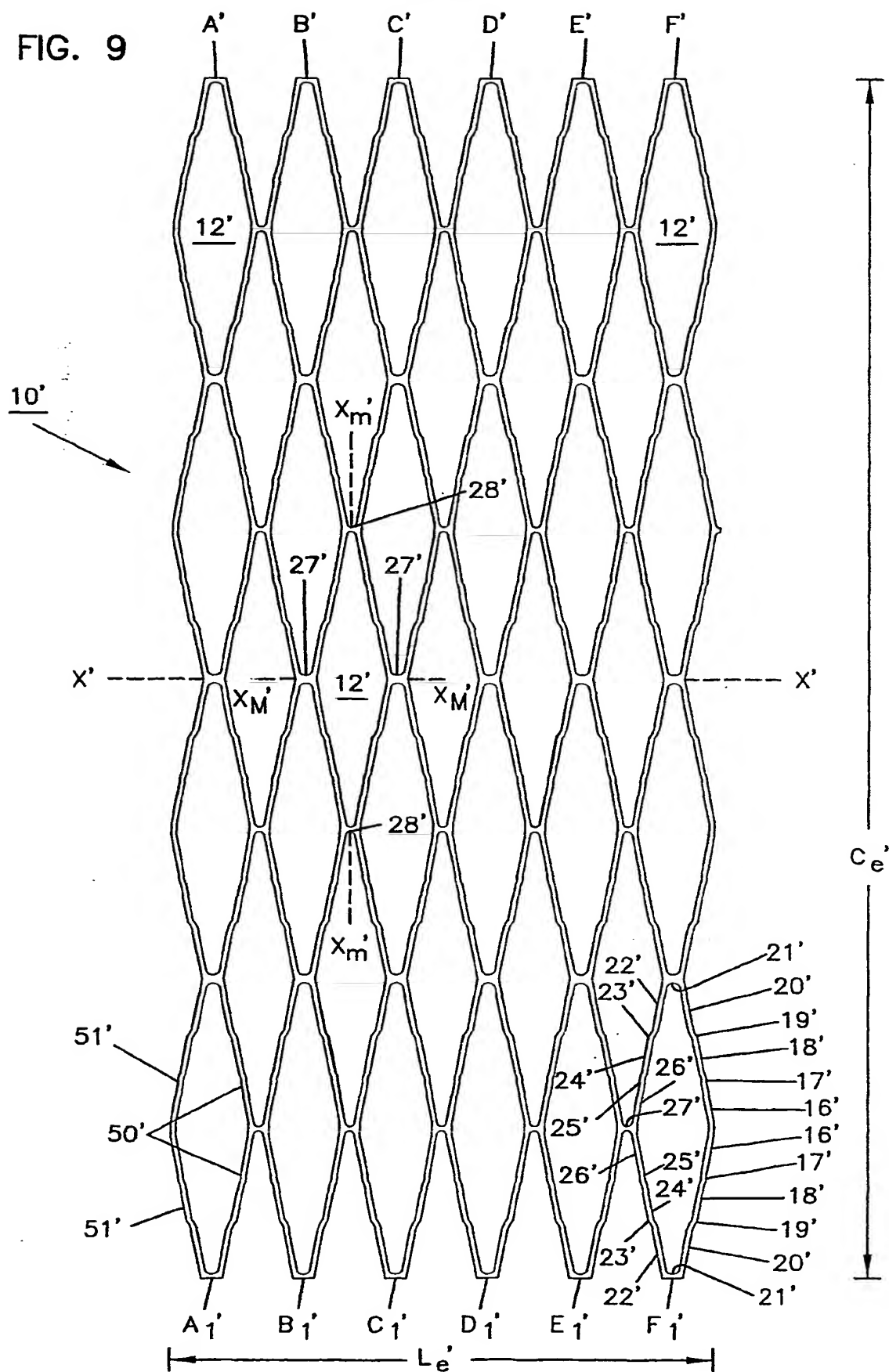


FIG.10

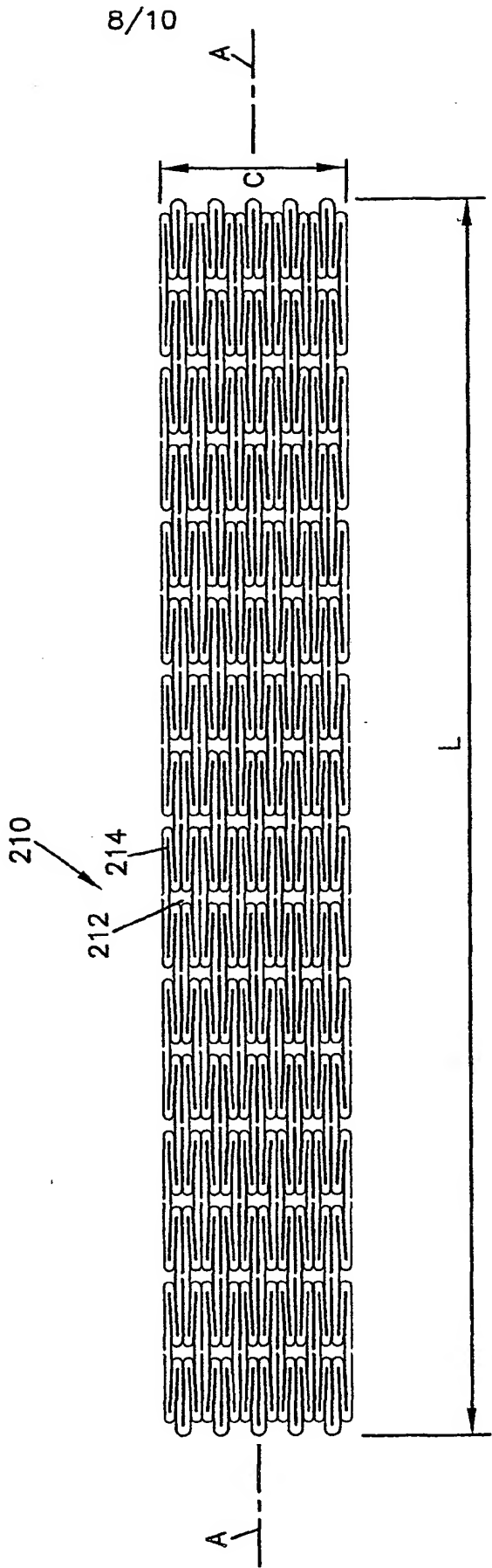
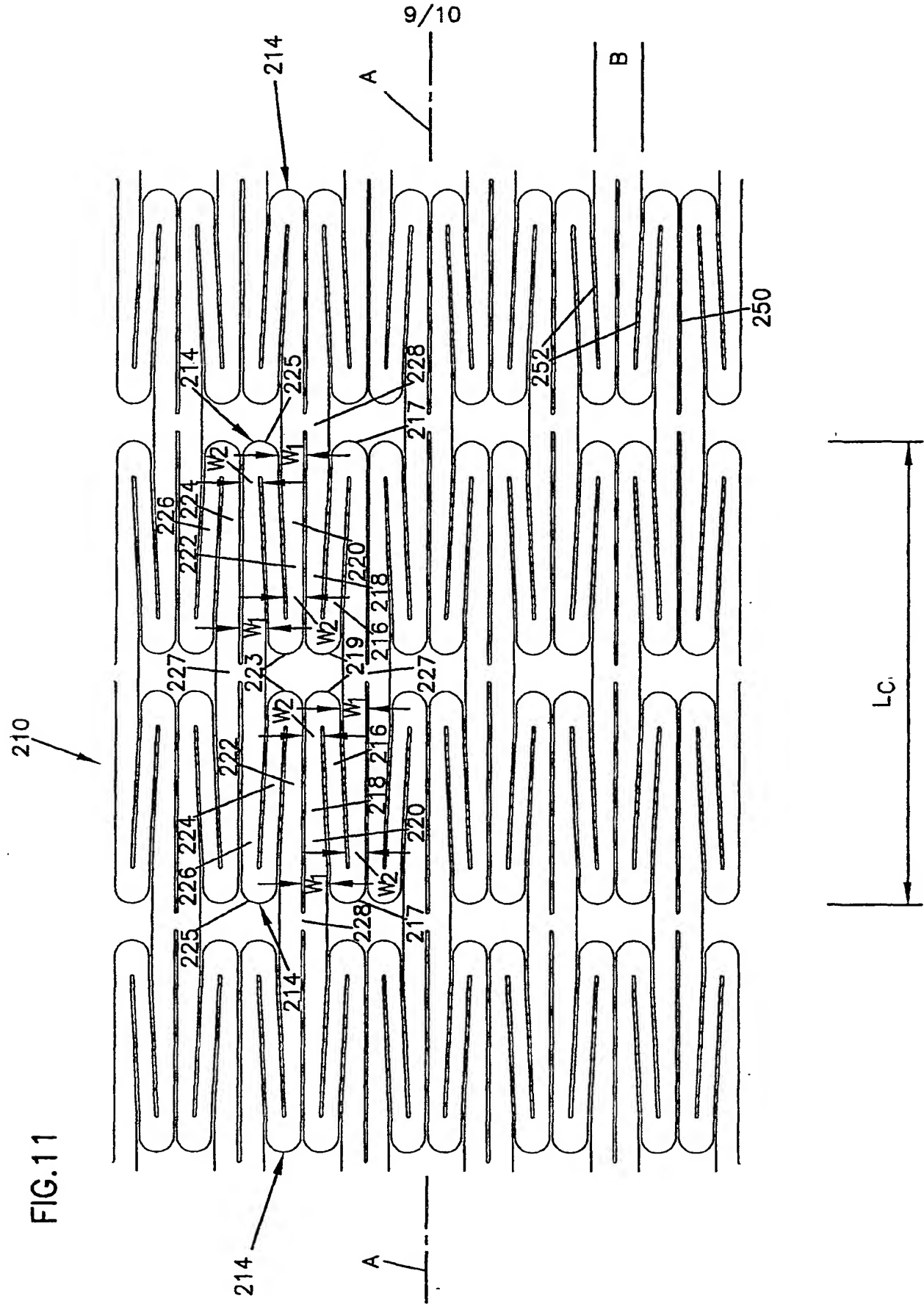
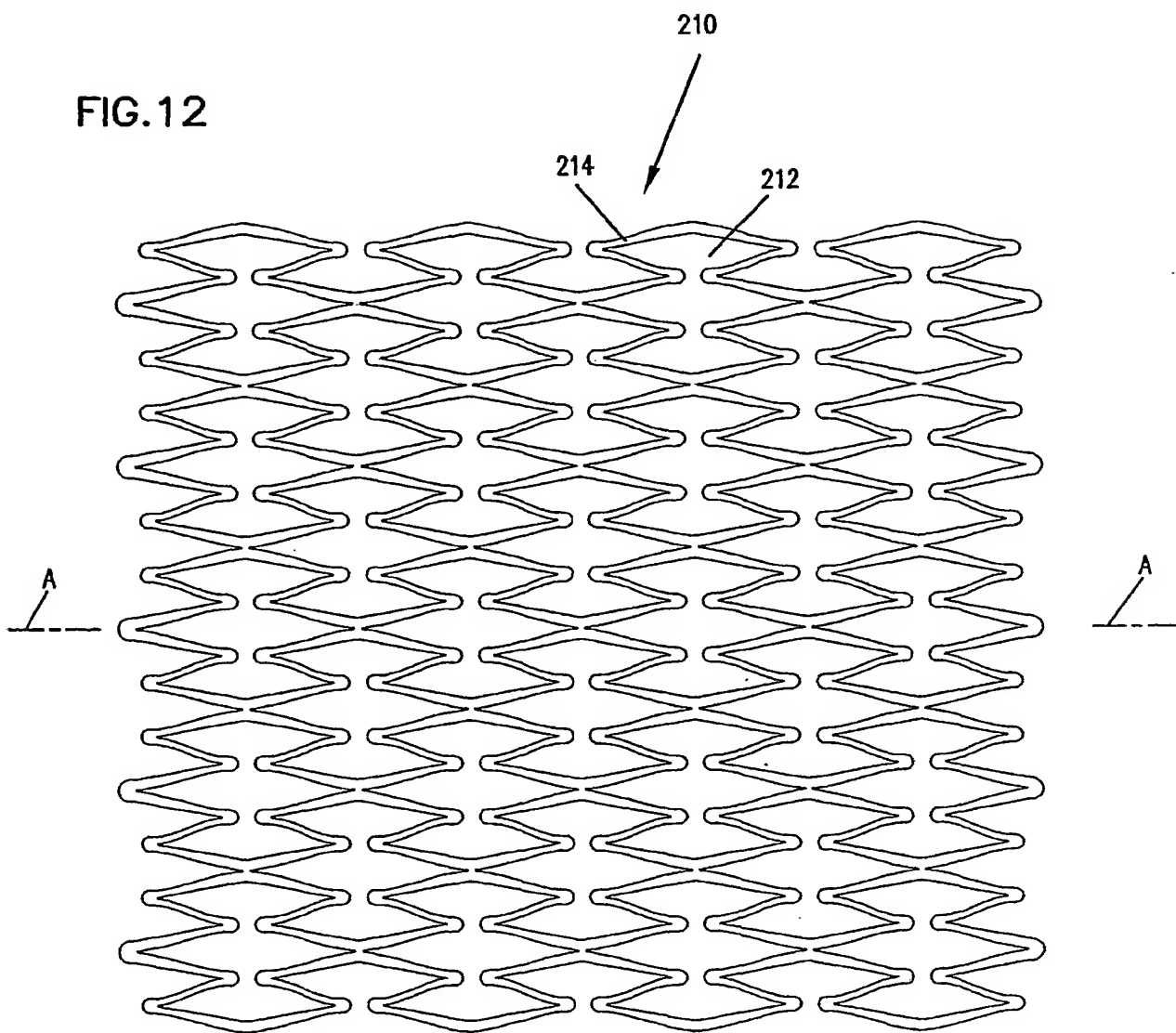


FIG.11



10/10

FIG.12



(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
25 July 2002 (25.07.2002)

PCT

(10) International Publication Number  
WO 02/056795 A3

(51) International Patent Classification<sup>7</sup>: A61F 2/06

(21) International Application Number: PCT/US02/01597

(22) International Filing Date: 18 January 2002 (18.01.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
09/765,725 18 January 2001 (18.01.2001) US

(71) Applicant: INTRATHERAPEUTICS, INC. [US/US];  
651 Campus Drive, St. Paul, MN 55112 (US).

(72) Inventor: THOMPSON, Paul, J.; 9125-40 1/2 Avenue  
North, New Hope, MN 55427 (US).

(74) Agent: BRUESS, Steven, C.; Merchant & Gould P.C.,  
P.O. Box 2903, Minneapolis, MN 55402-0903 (US).

(81) Designated States (national): AE, AG, AL, AM, AT, AU,  
AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU,

CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH,  
GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC,  
LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW,  
MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG,  
SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VN,  
YU, ZA, ZM, ZW.

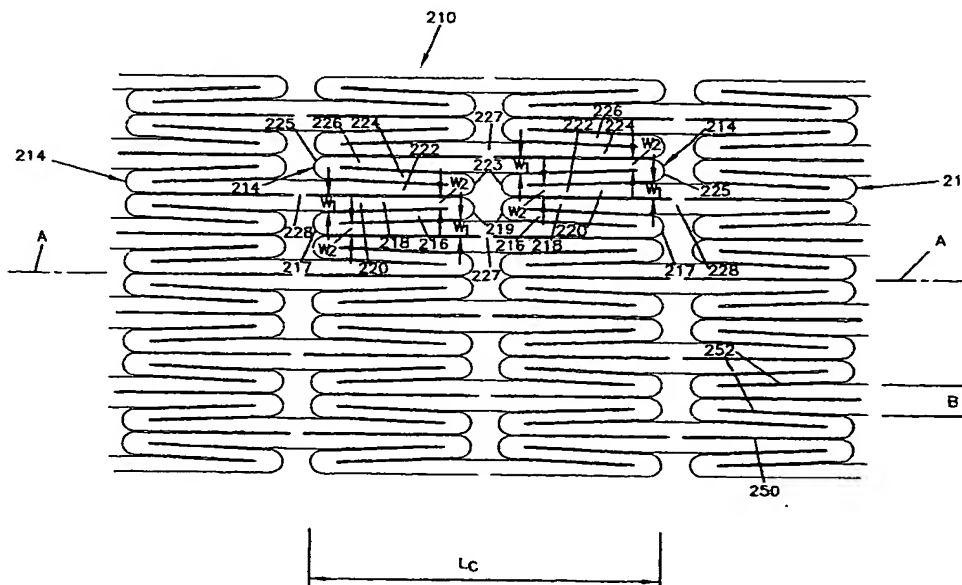
(84) Designated States (regional): ARIPO patent (GH, GM,  
KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW),  
Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),  
European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR,  
GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent  
(BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR,  
NE, SN, TD, TG).

Published:  
— with international search report

(88) Date of publication of the international search report:  
27 February 2003

For two-letter codes and other abbreviations, refer to the "Guid-  
ance Notes on Codes and Abbreviations" appearing at the begin-  
ning of each regular issue of the PCT Gazette.

(54) Title: STENT



(57) Abstract: The present disclosure relates to a stent including a stent body having a stent axis. The stent body includes structural members defining openings through the stent body. The structural members are provided with regions having different widths (W1, W2). The relative sizes of the widths (W1, W2) are selected to control the length of the stent body as the stent body is radially expanded from an un-deployed orientation to a deployed orientation. In one embodiment, the regions having different widths are provided by tapering the widths of selected segments of the structural member.

WO 02/056795 A3

# INTERNATIONAL SEARCH REPORT

Int. Application No  
PCT/US 02/01597

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 A61F2/06

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 A61F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 997 115 A (PROGRAFT MEDICAL INC) 3 May 2000 (2000-05-03)	20
A	page 3, line 22,23; claims 1,16; figures 20-25	1-19, 21-31
A	WO 99 39660 A (ROUSSIGNE MAURICE ;NADAL GUY (FR); BRAUN CELSA SA (FR)) 12 August 1999 (1999-08-12) page 15, line 18,19; figures 3,12,13	1-31
A	US 5 695 516 A (FISCHELL ROBERT E ET AL) 9 December 1997 (1997-12-09) cited in the application the whole document	1-31

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

### \* Special categories of cited documents :

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
- \*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

- \*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- \*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- \*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- \*G\* document member of the same patent family

Date of the actual completion of the international search

27 September 2002

Date of mailing of the international search report

07/10/2002

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax (+31-70) 340-3016

Authorized officer

Korth, C-F

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 02/01597

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 0997115	A	03-05-2000	US 6165210 A	26-12-2000
			US 5876432 A	02-03-1999
			EP 0997115 A2	03-05-2000
			AU 690684 B2	30-04-1998
			AU 2379595 A	23-10-1995
			CA 2157575 A1	12-10-1995
			CA 2261941 A1	12-10-1995
			EP 0754016 A1	22-01-1997
			JP 3129327 B2	29-01-2001
			JP 8509899 T	22-10-1996
			WO 9526695 A2	12-10-1995
			US 6001123 A	14-12-1999
			US 6017362 A	25-01-2000
			US 6331188 B1	18-12-2001
			US 6015429 A	18-01-2000
			US 5919225 A	06-07-1999
			US 5873906 A	23-02-1999
			AU 4757596 A	31-07-1996
			WO 9621404 A1	18-07-1996
WO 9939660	A	12-08-1999	FR 2774279 A1	06-08-1999
			FR 2784573 A1	21-04-2000
			FR 2784574 A1	21-04-2000
			EP 1052950 A1	22-11-2000
			WO 9939660 A1	12-08-1999
US 5695516	A	09-12-1997	NONE	

**THIS PAGE BLANK (USPTO)**